Wrocław University of Technology

In-situ monitoring of high doses of radiation

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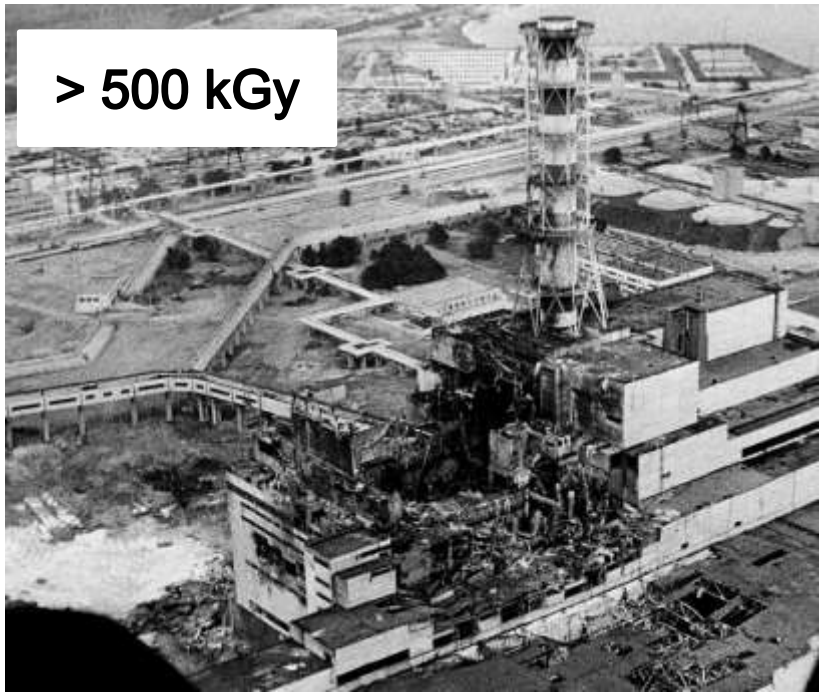
Motivaton

Chernobyl (at left) and Fukushima (at right) nuclear power plants after nuclear accidents.

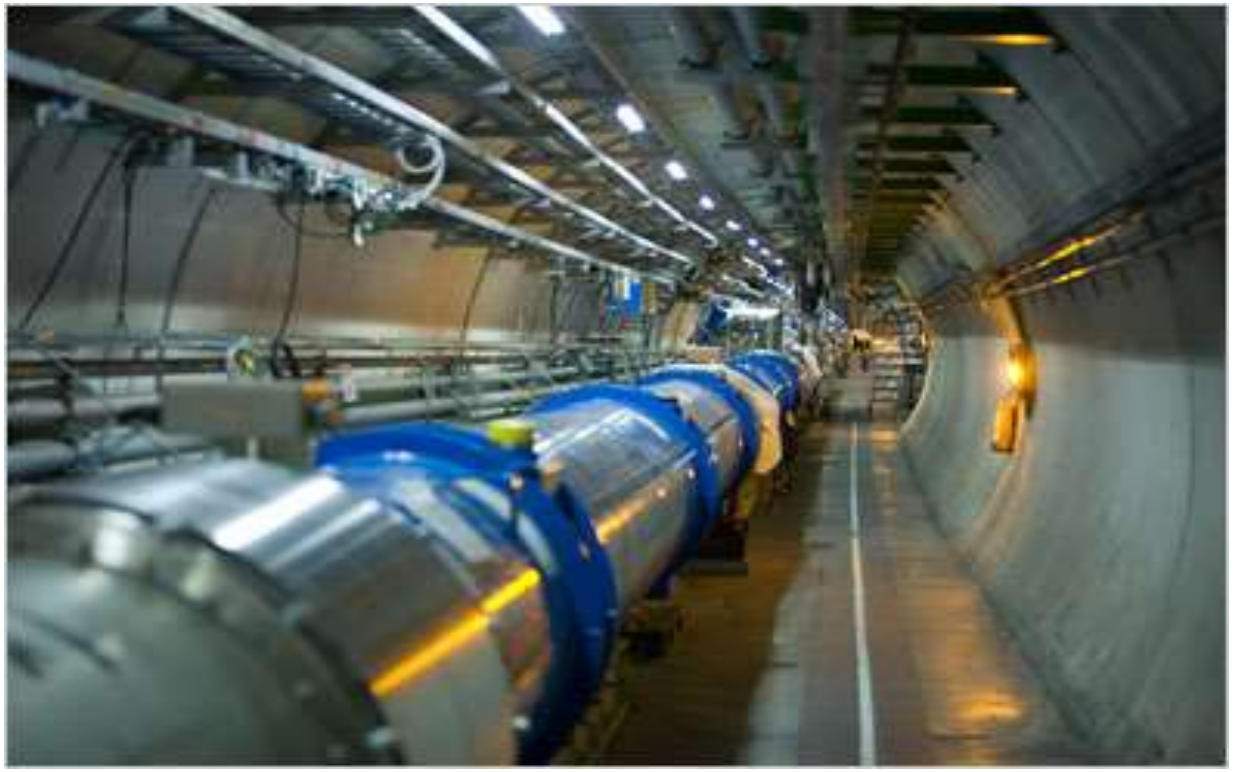


High radiation > 100 kGy doses in short term.

* International Nuclear Safety Center

Motivaton

Scientyfic / industy facility



Radiation level - low, but long-term dose high > 20 kGy.

* CERN accelerating science

High radiation doses ”measurements” - state of art:

> 20 kGy **only non-direct measurements** by:

- alanine dosimeters:
- range of measurement up to 1 MGy

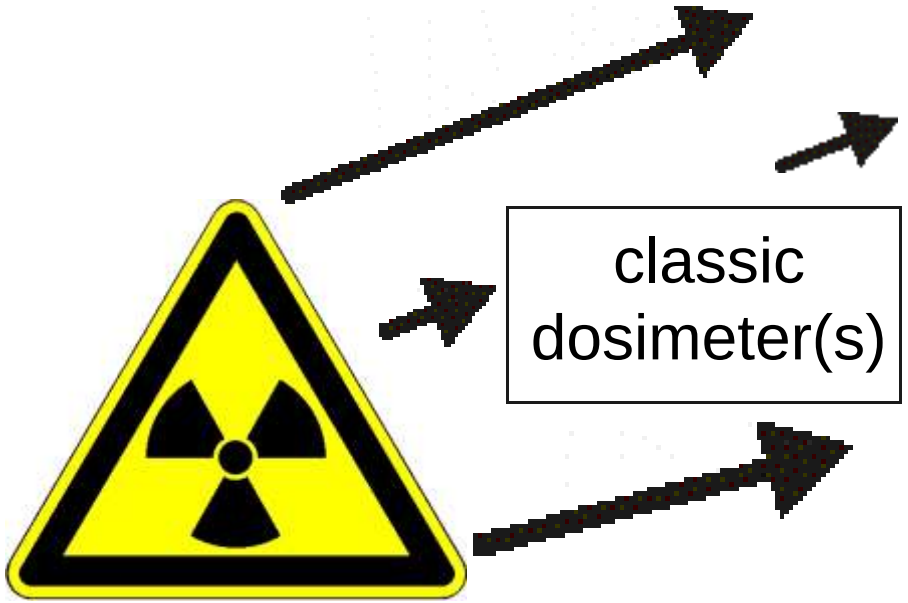
- photoluminescent dosimeters:
- range of measurement up to 1 MGy

- thermoluminescent dosimeters:
- range of measurement up to 1 MGy

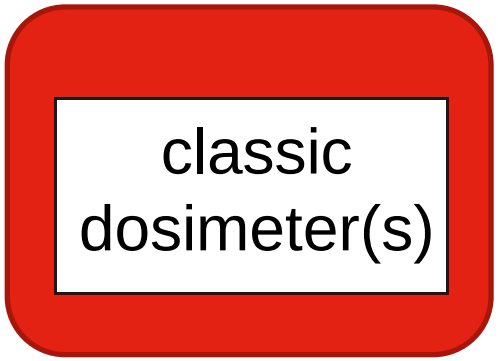
- hydrogen pressure dosimeters:
- range of measurement up to 10 MGy

Non-direct measurement

absorbed dose above 20 kGy



radiation source

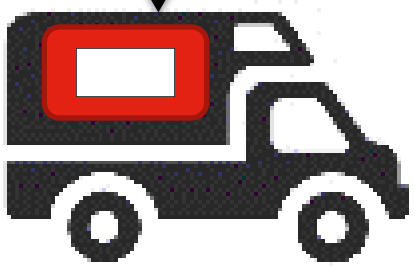


radiation-proof container

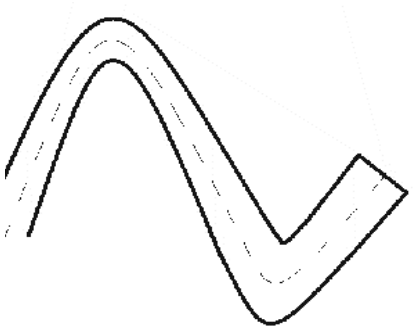
transport to the laboratory

Non-direct measurement

classic dosimeter(s)

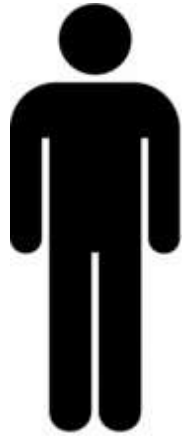


transport



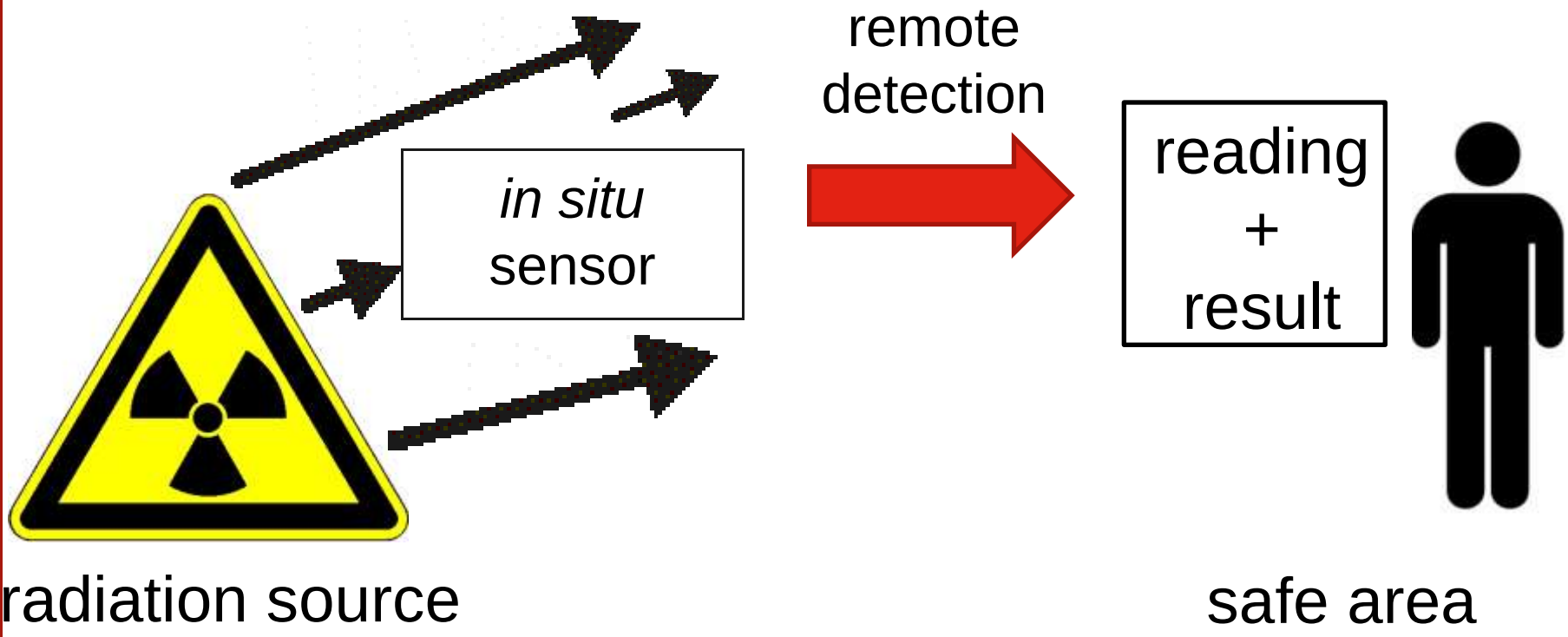
Laboratory

reading + analysis
= result
(estimation of dose)



Result: several hours to months

Wanted: new method of measurements of high-doses of radiation above 20 kGy

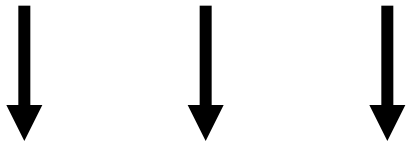


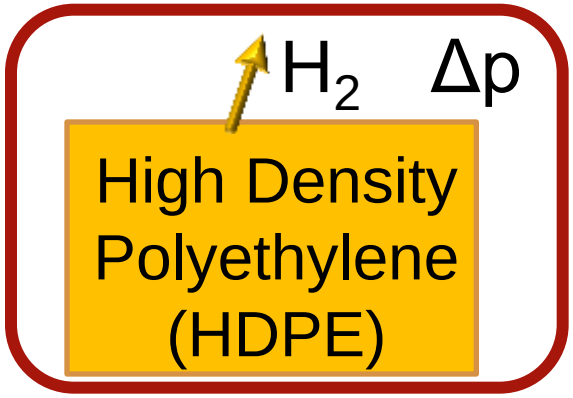
Problem: no sensors

Hydrogen pressure dosimeter - principle of the work

principle using from 1950's

high dose radiation

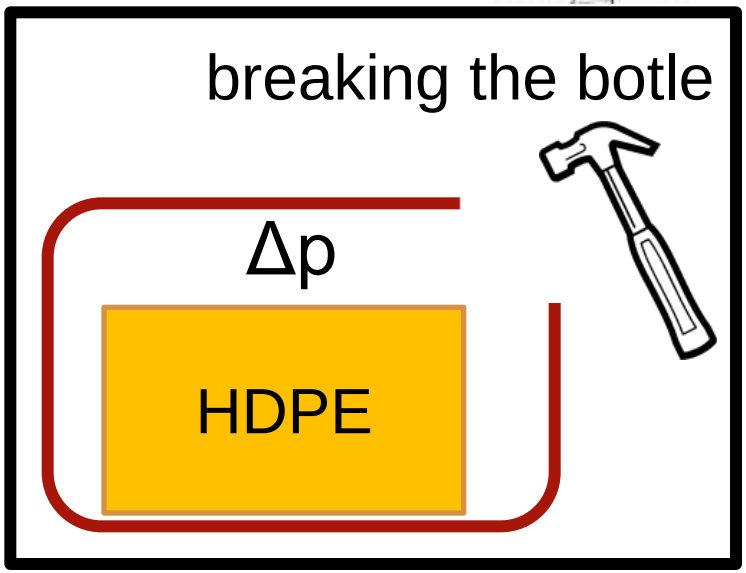




glass container with HDPE

transport

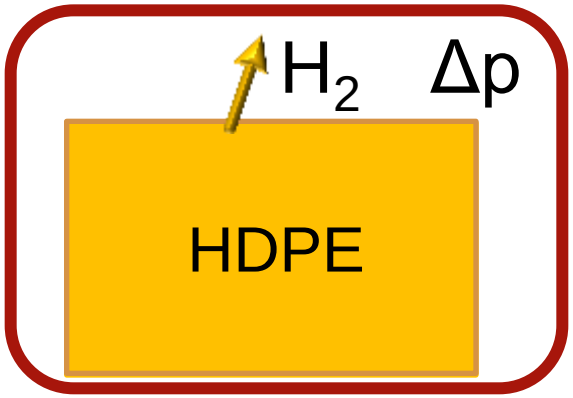
Laboratory



measurements by Bourdon gauge

Our goal

principle using
from 1950's



glass container
with HDPE

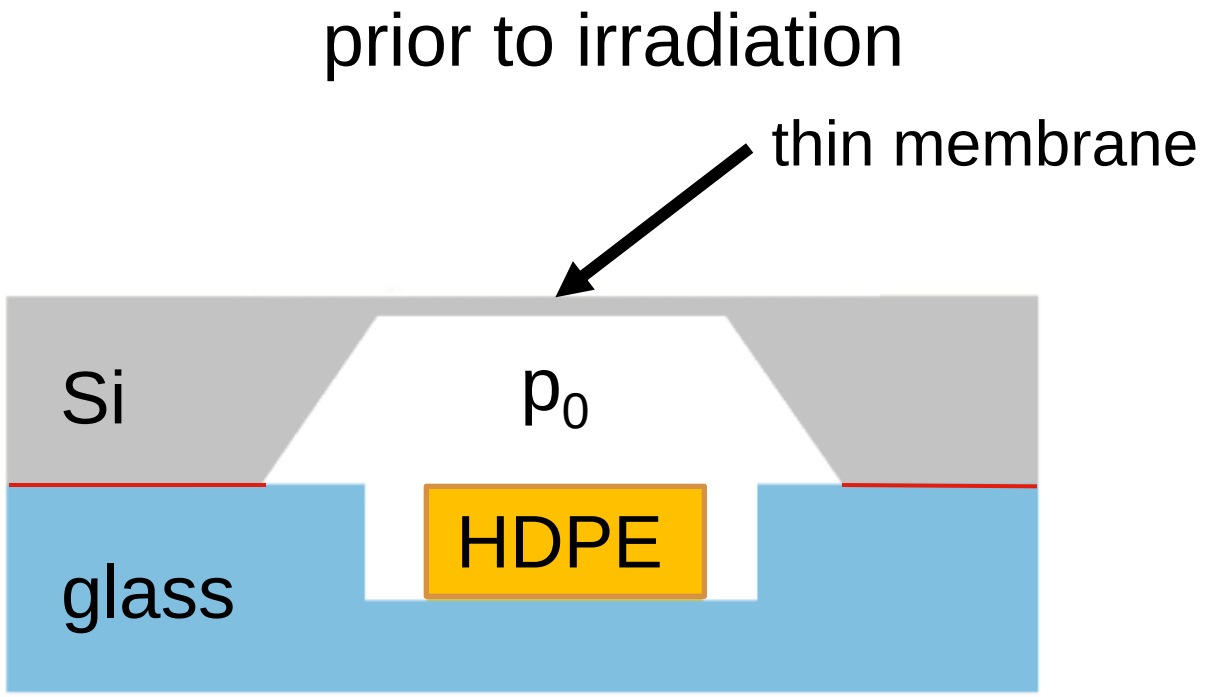
V ~ 100 cm³

new MEMS sensor
for continues measurements

miniaturization

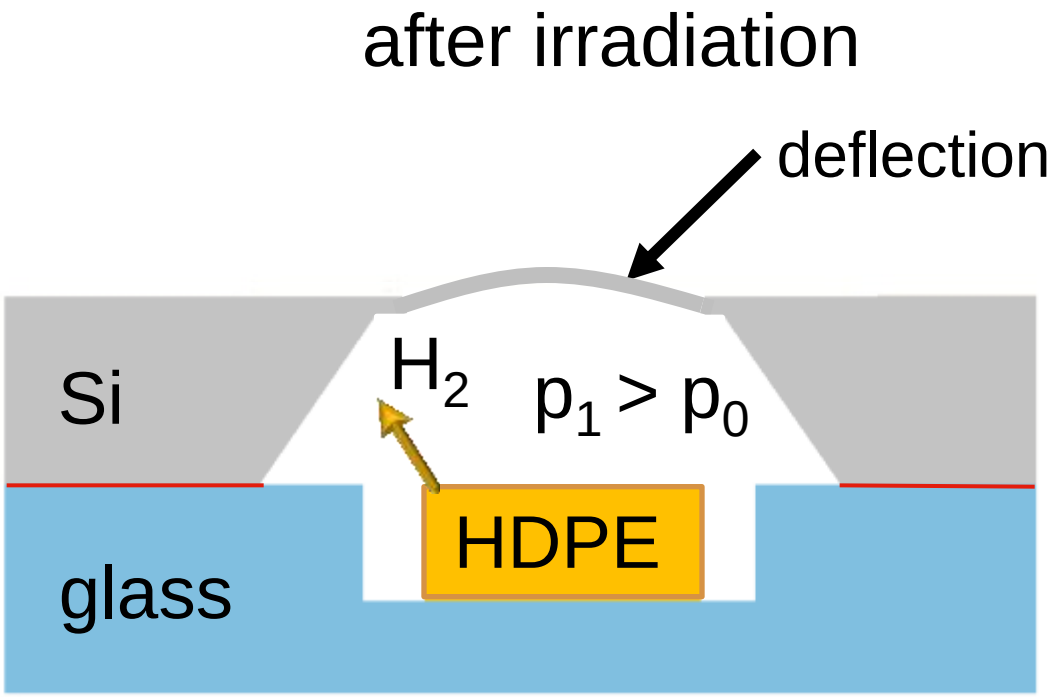
V ~ 10 mm³

Our new MEMS sensor - principle



p_0 = introductional pressure (after sealing)

Our new MEMS sensor - principle

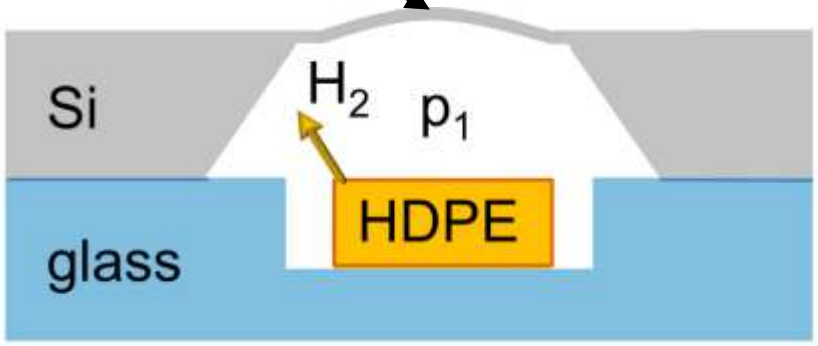


Irradiated HDPE degrades and releases atomic hydrogen

$$p_1 - p_0 = \Delta p = f(\text{dose})$$

Our new MEMS sensor - principle

deflection of membrane



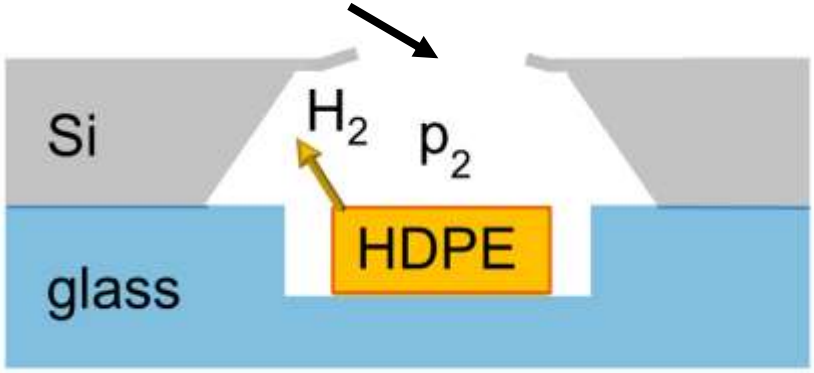
below maximal pressure/dose

Single membrane sensor

$p_1 < p_{max}$

proportional mode of detection possible

destruction of membrane



over maximal pressure/dose

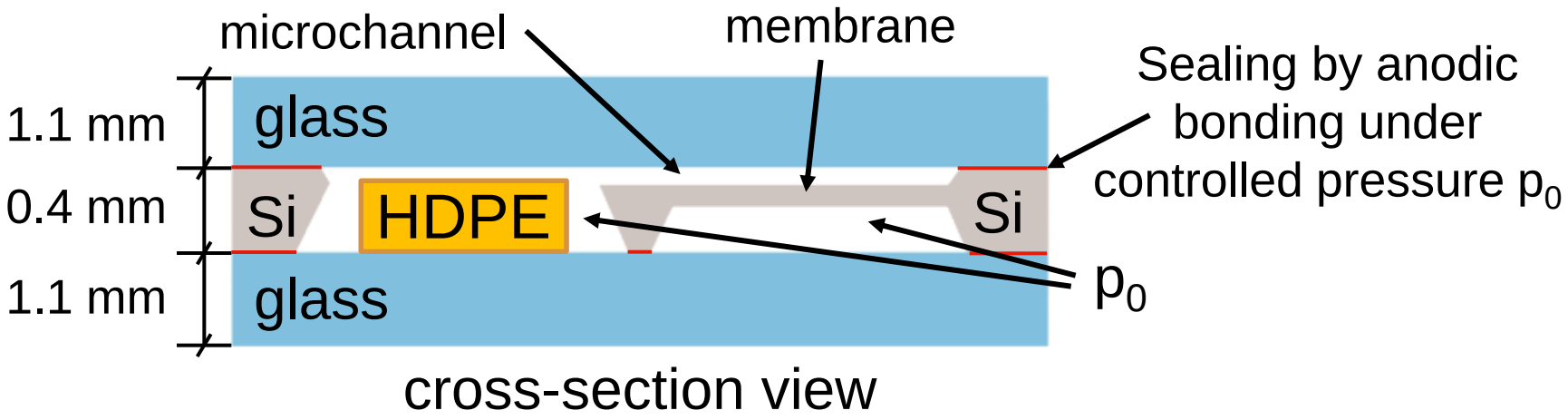
”Cascade” membranes sensor

$p_2 > p_{max}$

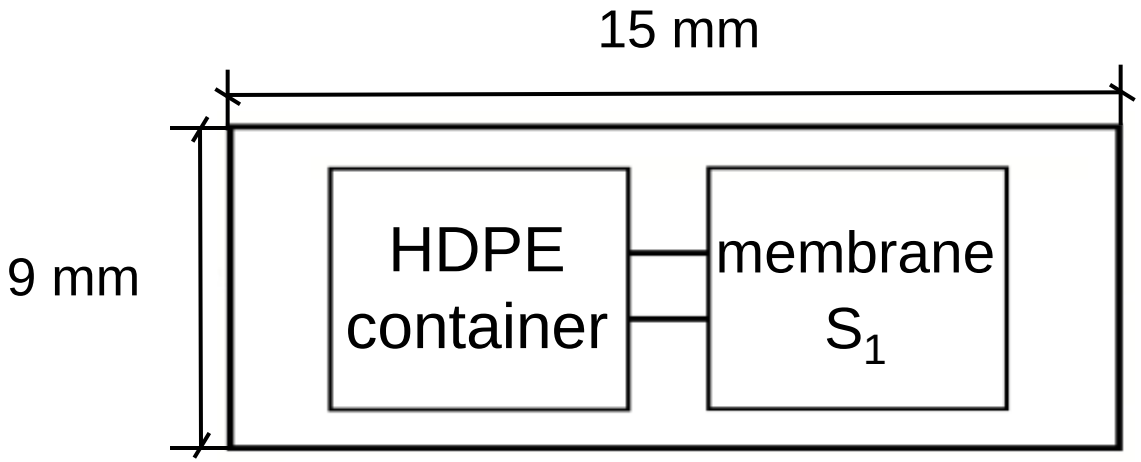
membrane of known mechanical properties discriminates doses

Technical realization

Single membrane proportional sensor



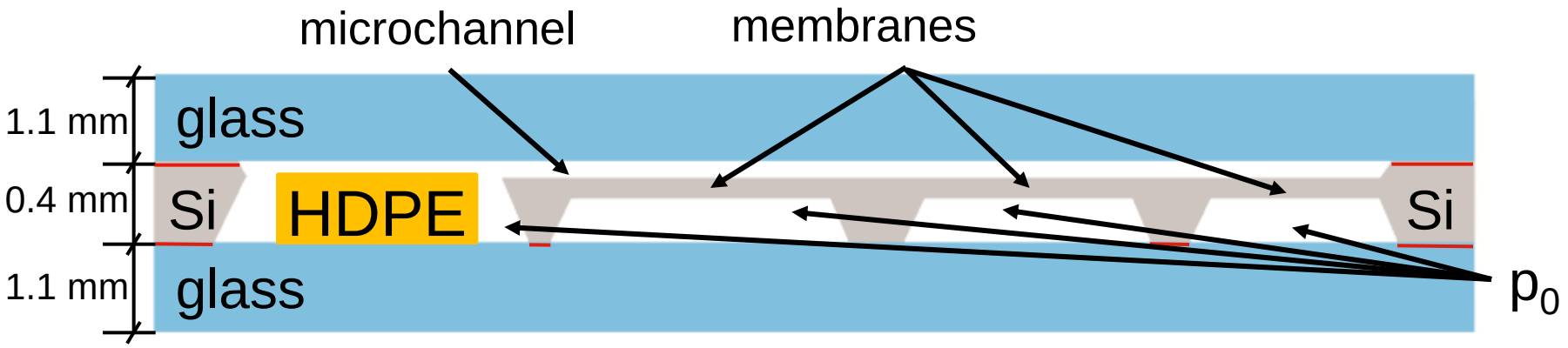
cross-section view



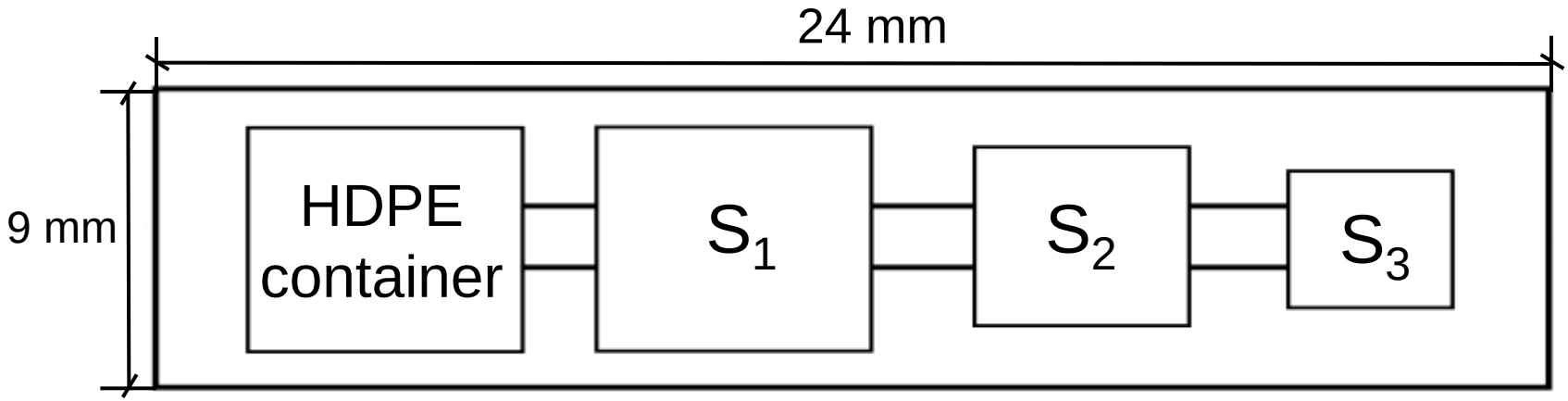
planar view

scheme not in scale

Technical realization
„Cascade” membranes treshold sensor



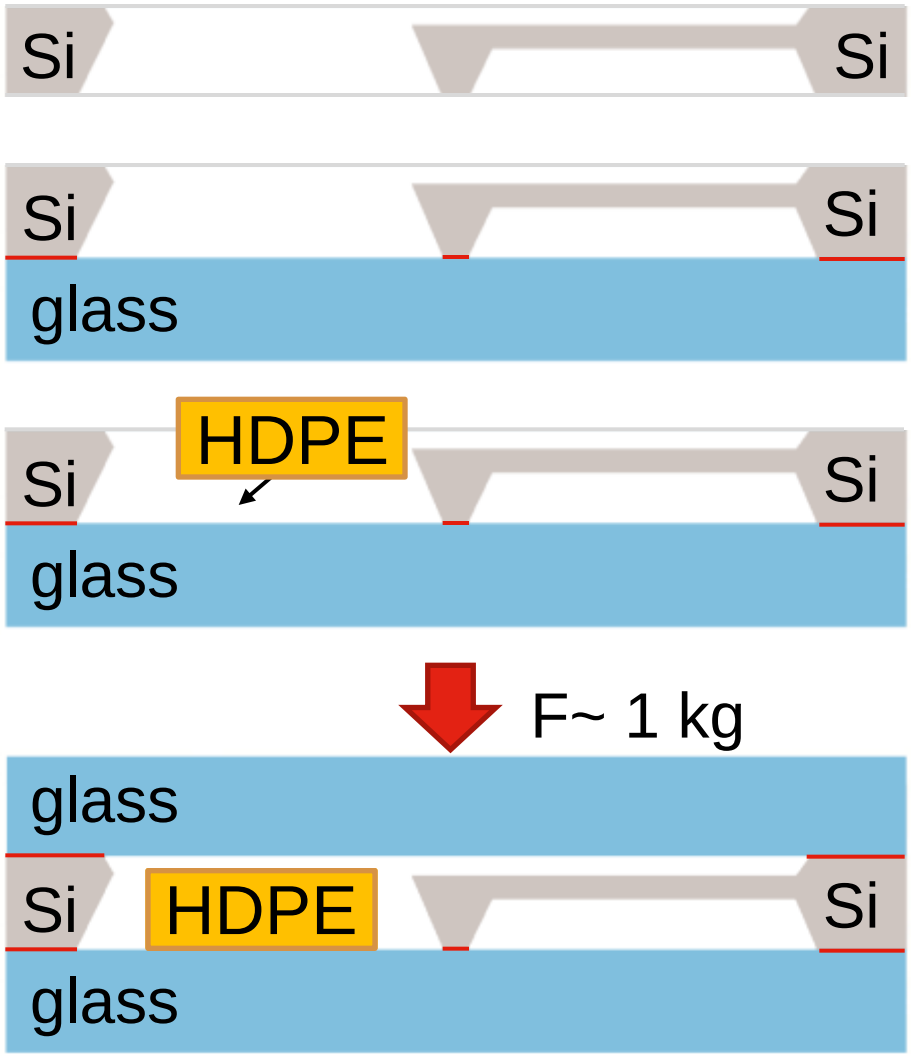
cross-section view



planar view

scheme not in scale

Fabrication - process



double-side deep wet etching
in KOH 80°C, 10M KOH

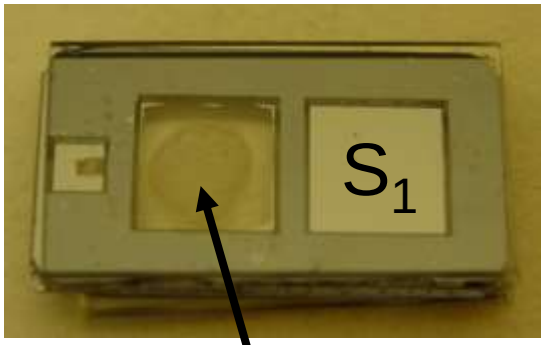
first anodic bonding in N_2
450°C, 1000 V

placing of solid HDPE pill

second anodic bonding in N_2
300°C, 1200 V

MEMS sensors at a glance

Single membrane sensor

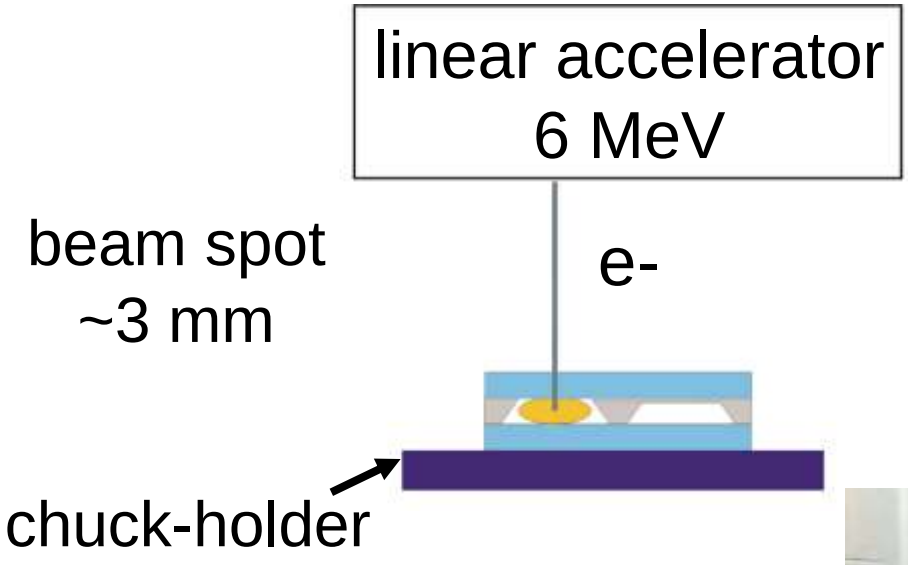


”Cascade” membranes sensor

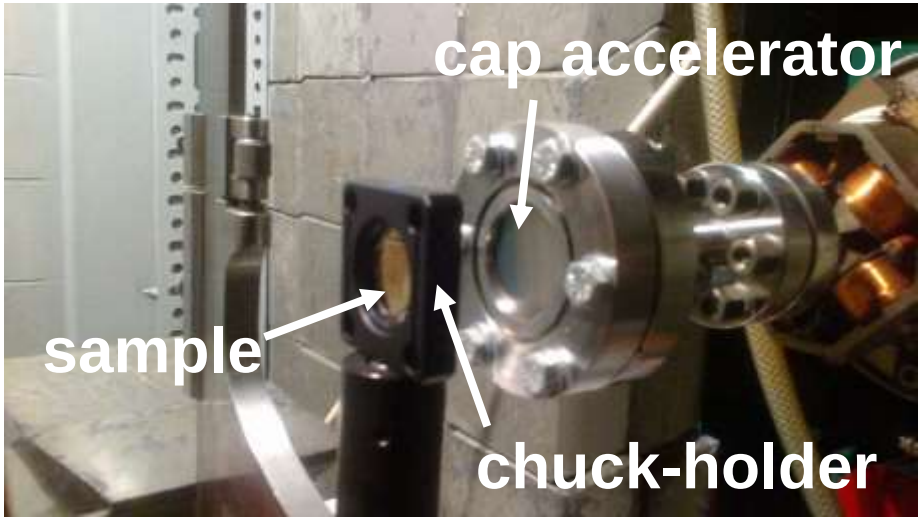
container with HDPE

Several tens of sensors have been successfully fabricated.

Irradiation



total dose
20 kGy < x < 120 kGy



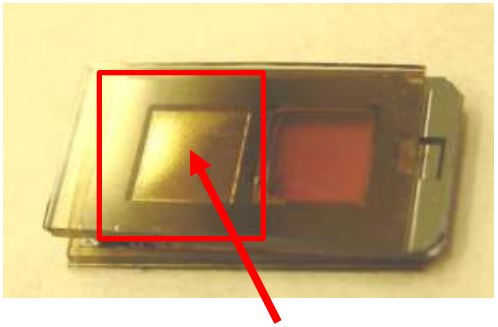
high energy electron beam

Results of irradiation

Single membrane proportional sensor

sensor before irradiation

sensor after irradiation



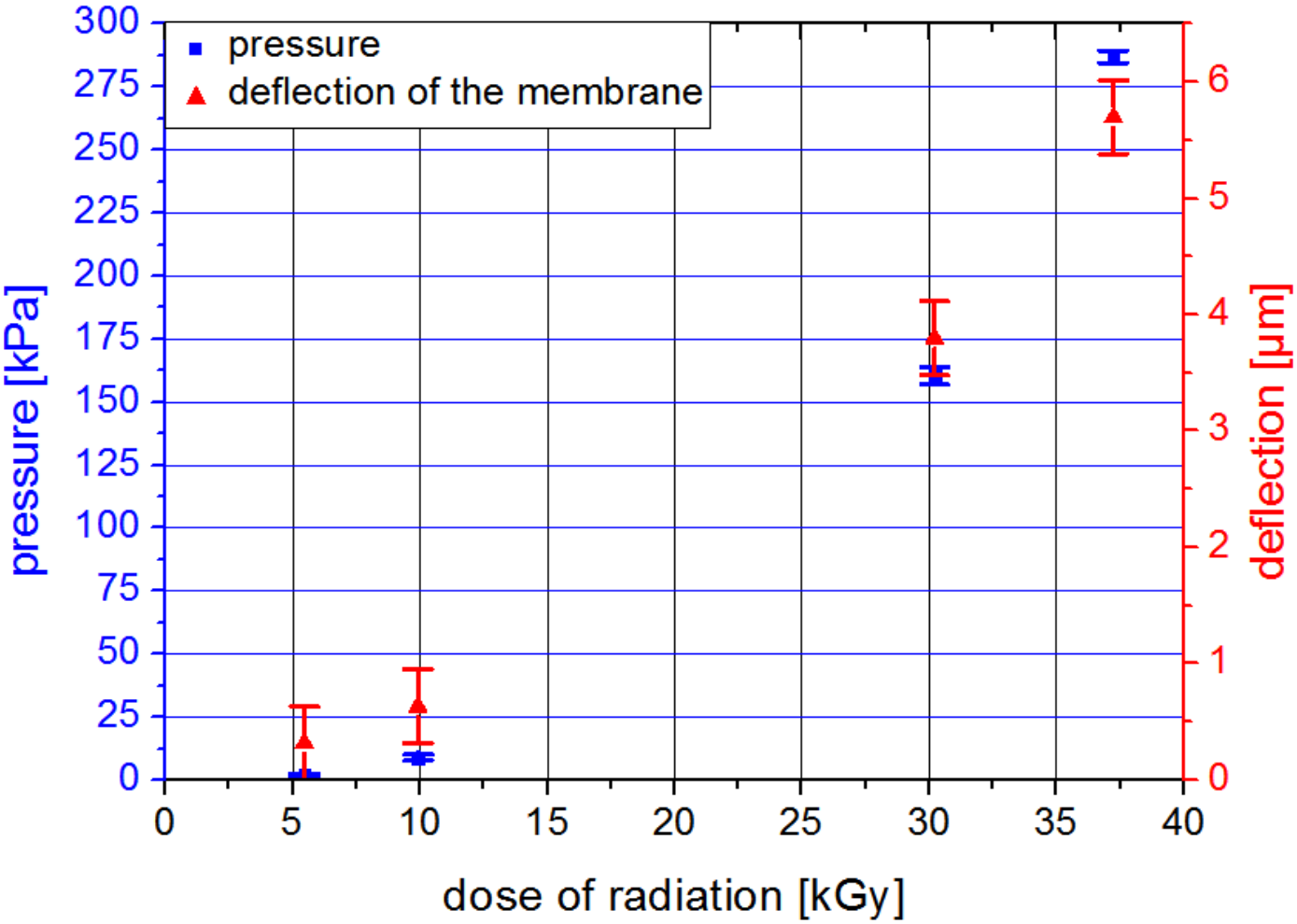
deflected membrane

25 mm^2 and 30 µm thick membrane – deflected @ 10 kGy dose

Sensors have been fabricated in MEMSlab facilities at Wrocław University of Technology.

Sensors have been tested in National Center for Nuclear Research in Otwock / Świerk

Data processing toward sensor

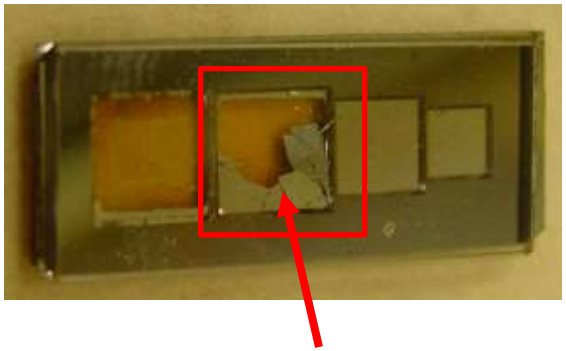


Results of irradiation

”Cascade” membranes treshold sensor

sensor before irradiation

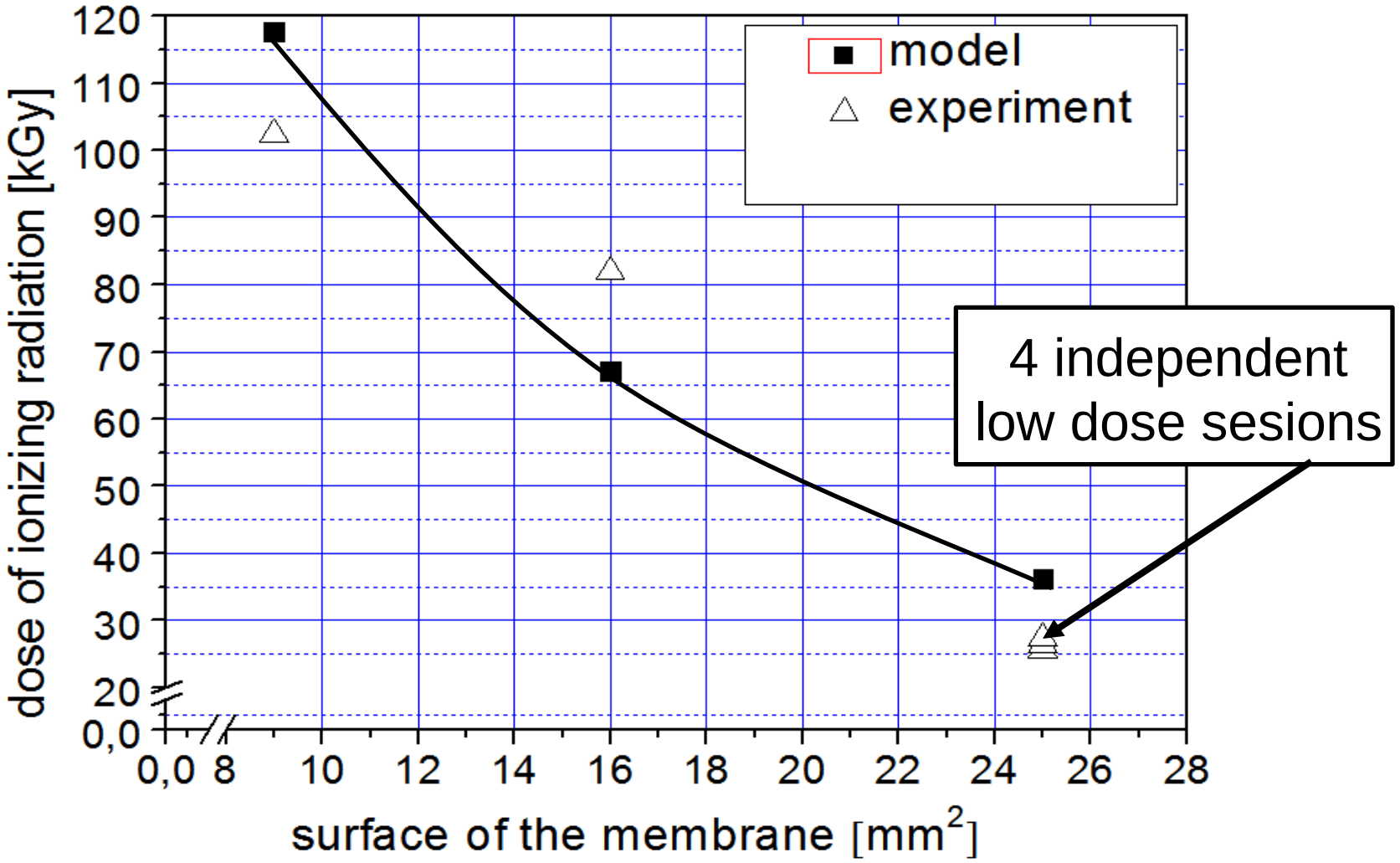
sensor after irradiation



destroyed membrane

25 mm^2 / 30 µm thick membrane – destroyed at 26.8 kGy dose

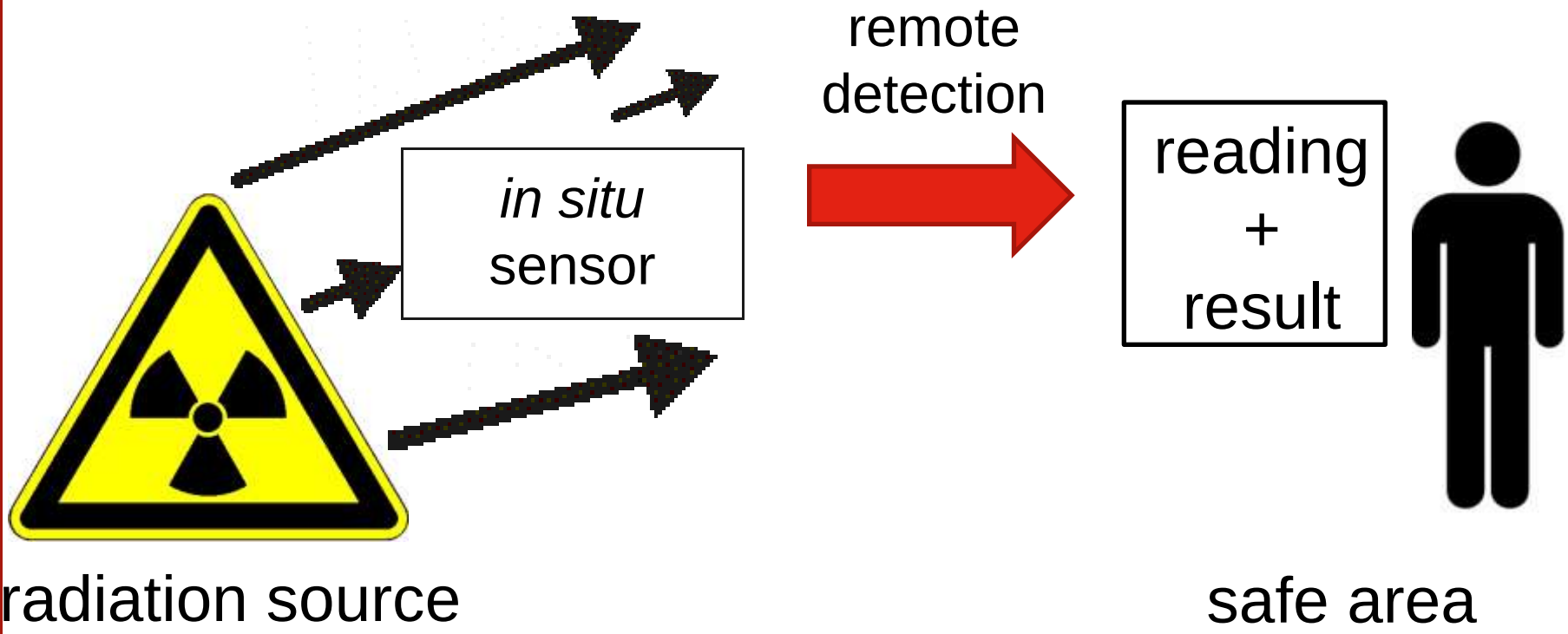
Data processing toward sensor



Short interim summary:

- MEMS miniature sensors for detection of high doses of ionizing radiation have been fabricated and tested
- Doses up to 120 kGy have been successfully detected
- High radiation doses 10 – 120 kGy in situ detection by small MEMS sensor have been shown for the first time
- **„Cascade" membrane sensor as dose treshold sensor is ready-to-use!**

Single membrane sensor - proportional operation mode

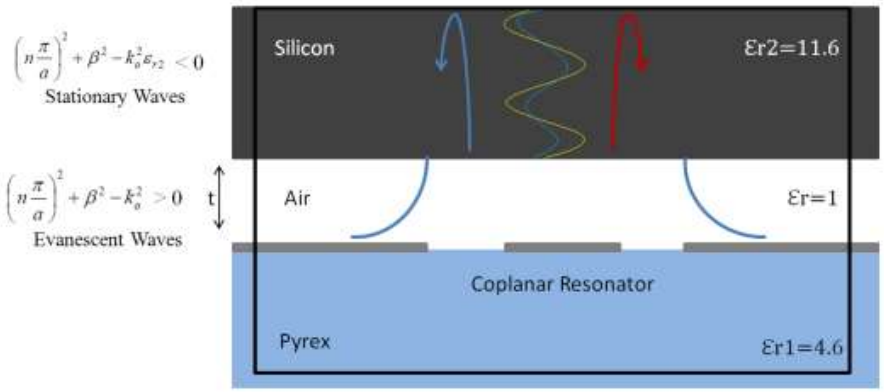


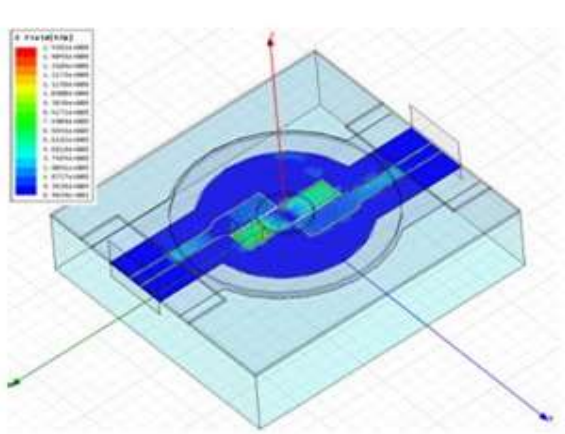
Remote detection

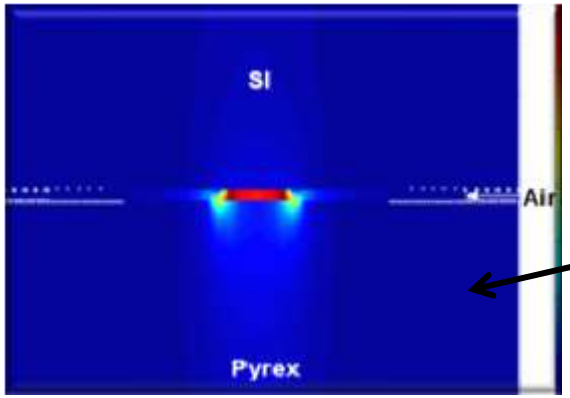
Radar remote detection based on LAAS technology

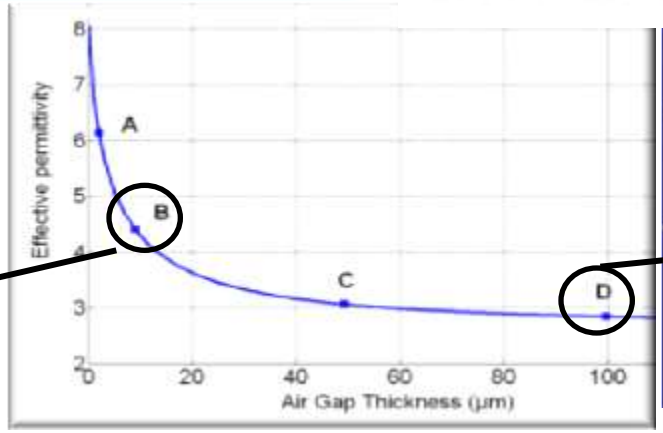
Modification of EM coupling between resonator and silicon membrane

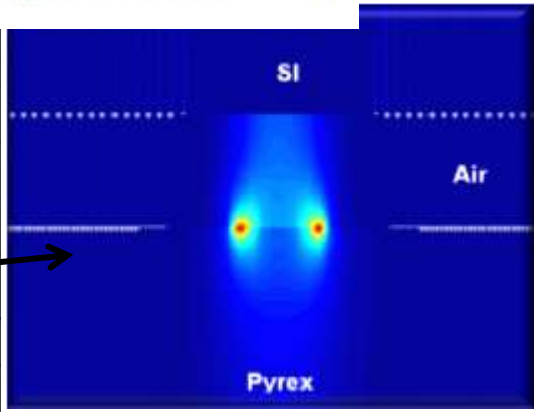
- High sensitivity to membrane displacement (Air gap : 1µm to 10µm)



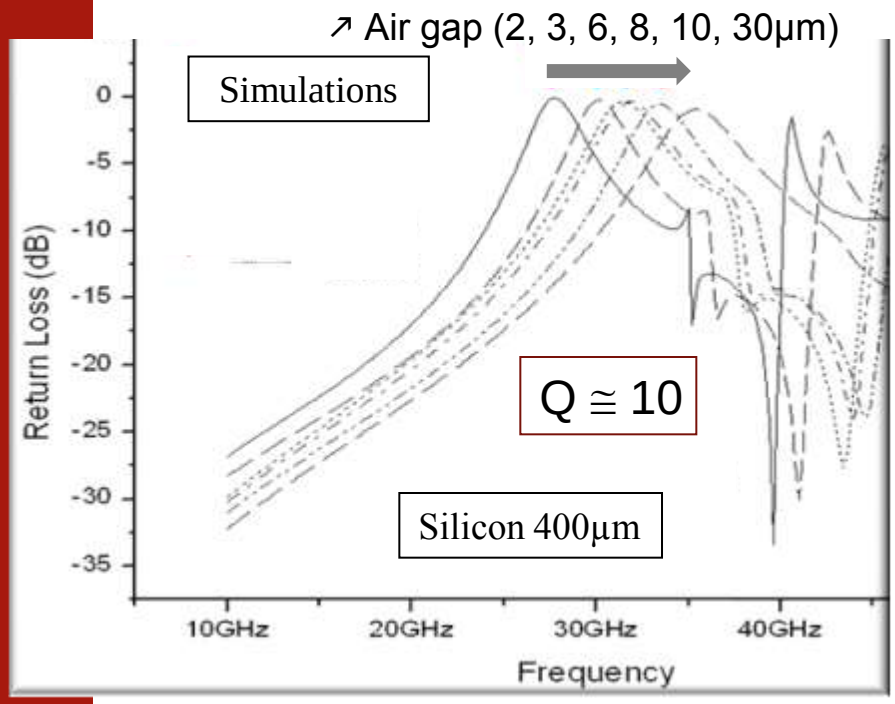


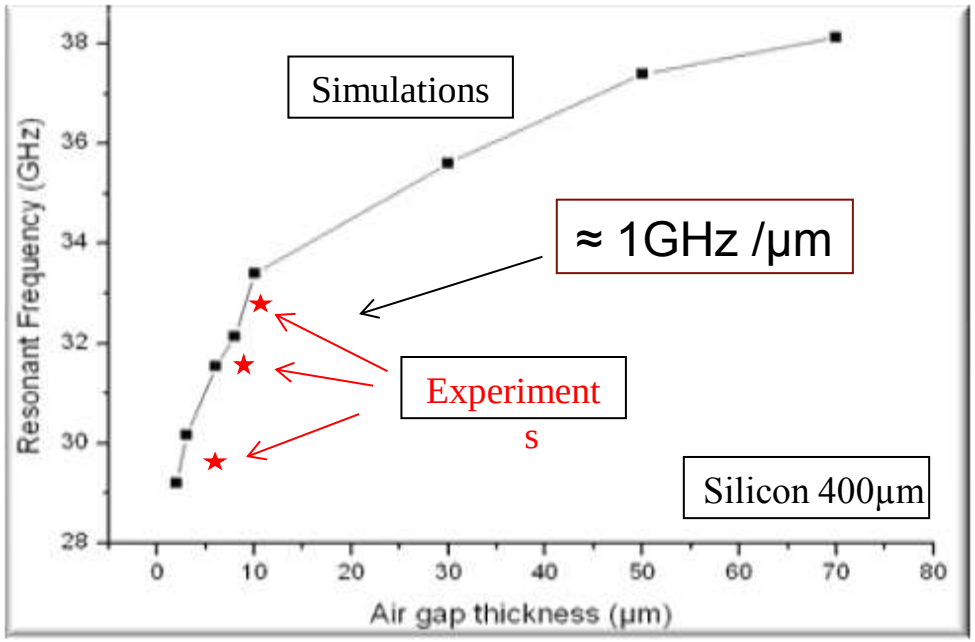




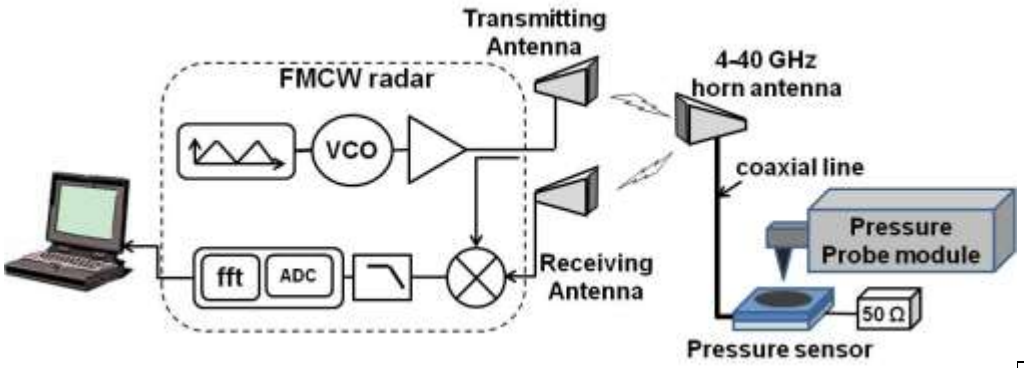


Radar remote detection based on LAAS technology

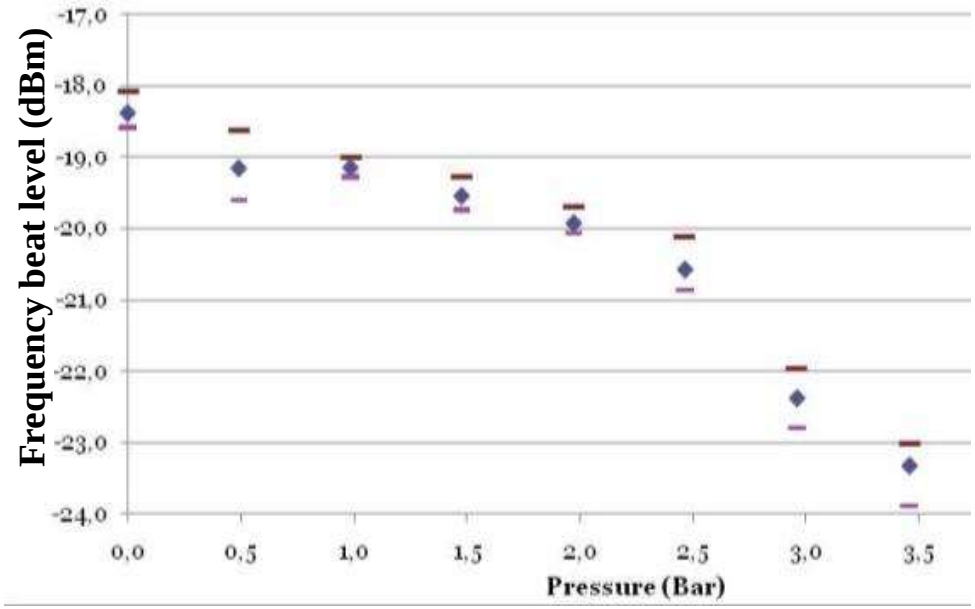




Radar remote detection based on LAAS technology

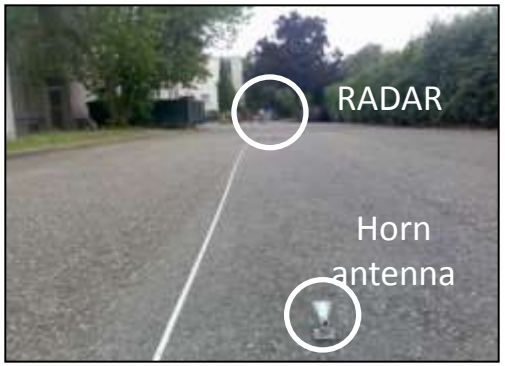


30GHz Radar prototype

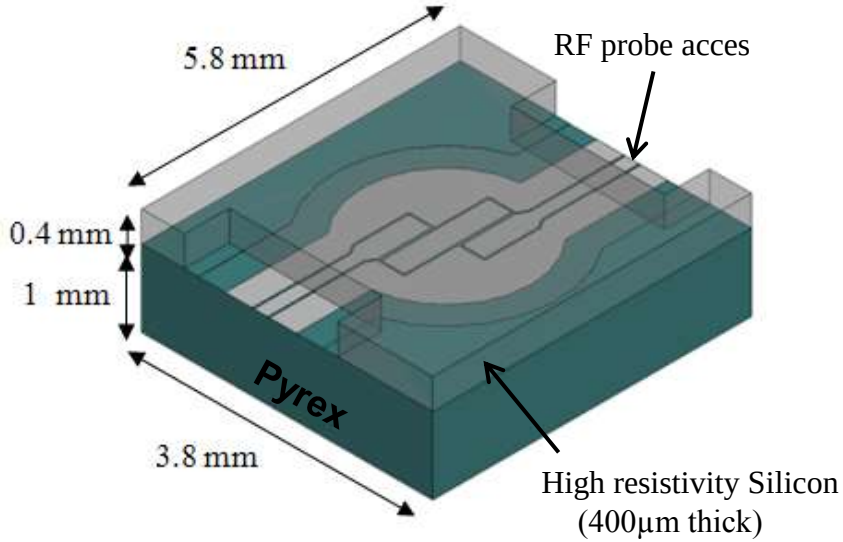


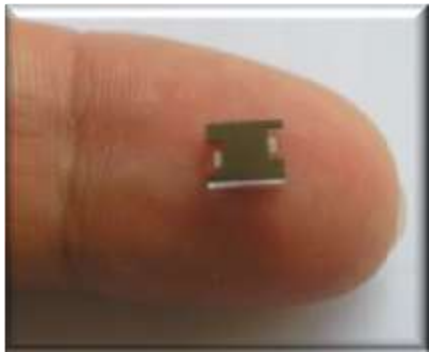
Interrogation distance :

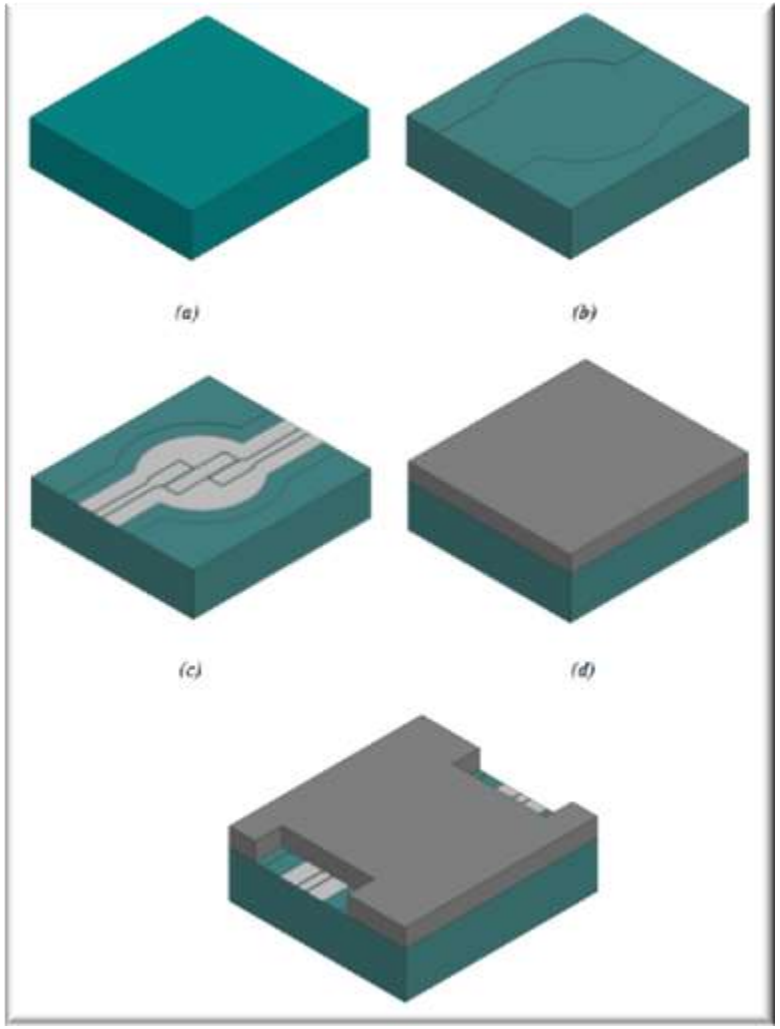
- 3 m (pressure sensor)
- 30m (Antenna loaded with impedance)
  → >> 30m expected



Radar remote detection based on CNRS-LAAS (Toulouse, Fance) technology







MEMS high-dose radiation sensor

DOSIMEMS Project **„Passive, wireless MEMS dosimeter for the high radiation dose monitoring”**, financed by the European Commission under the Seventh Framework Programme FP7, MNT-ERA.NET.

EUROPEAN COMMISSION

mnt-era.net

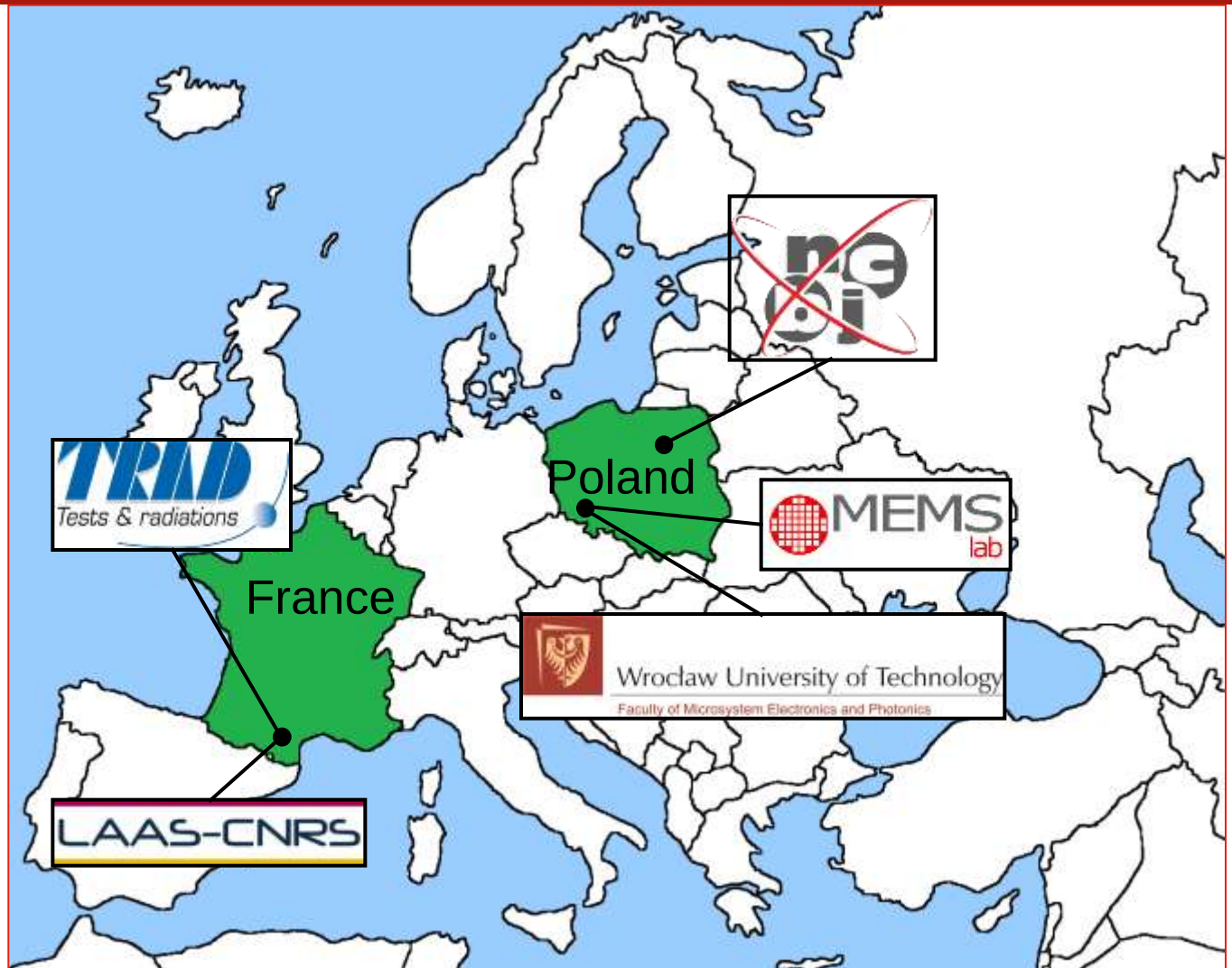
SEVENTH FRAMEWORK PROGRAMME

RÉGION MIDI-PYRÉNÉES

Wrocław University of Technology
Faculty of Microsystem Electronics and Photonics

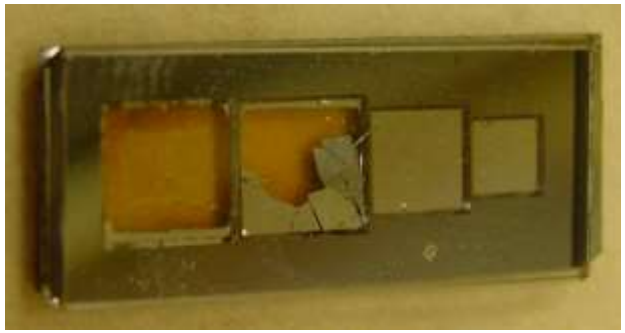
Responsible for development of the sensor technology

DOSIMEMS project- participants



Sensors of high doses of radiation – potential application

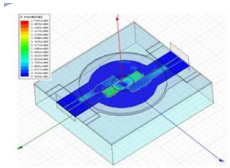
”Cascade” membranes treshold sensor



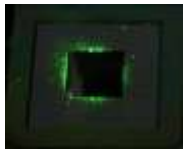
+ simple eye controll

Single membrane proportional sensor

+ remote controll



Radar

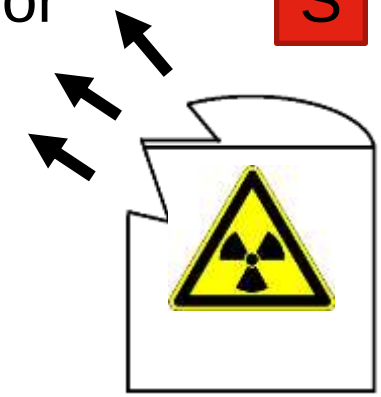


Optical

Sensors of high doses of radiation – potential application

Monitoring of high doses of radiation after the disaster in harsh environment.

S - radiation sensor

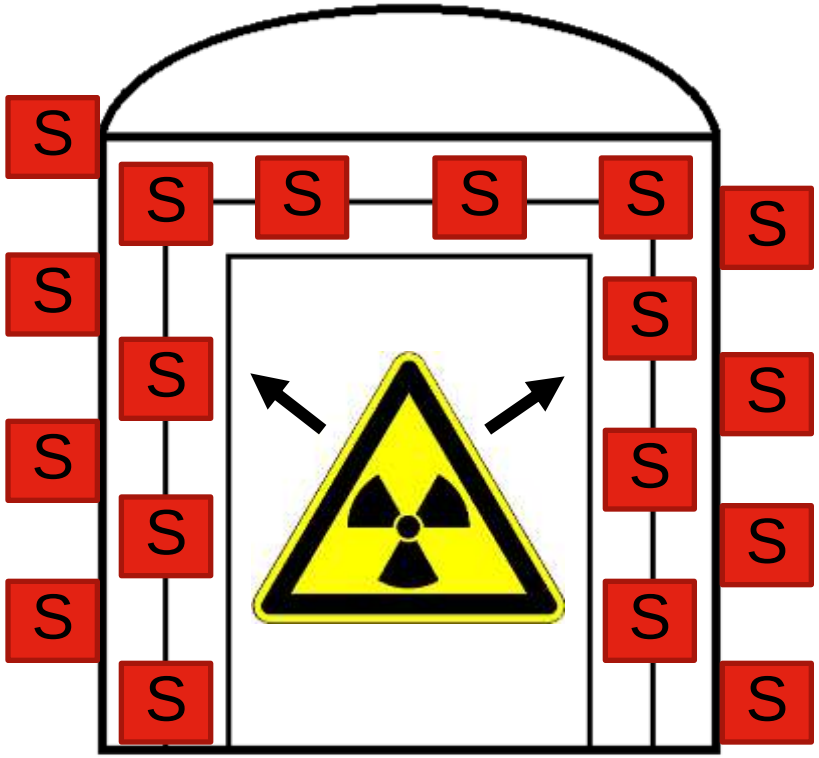


damaged reactor

polluted area

Sensors of high doses of radiation – potential application

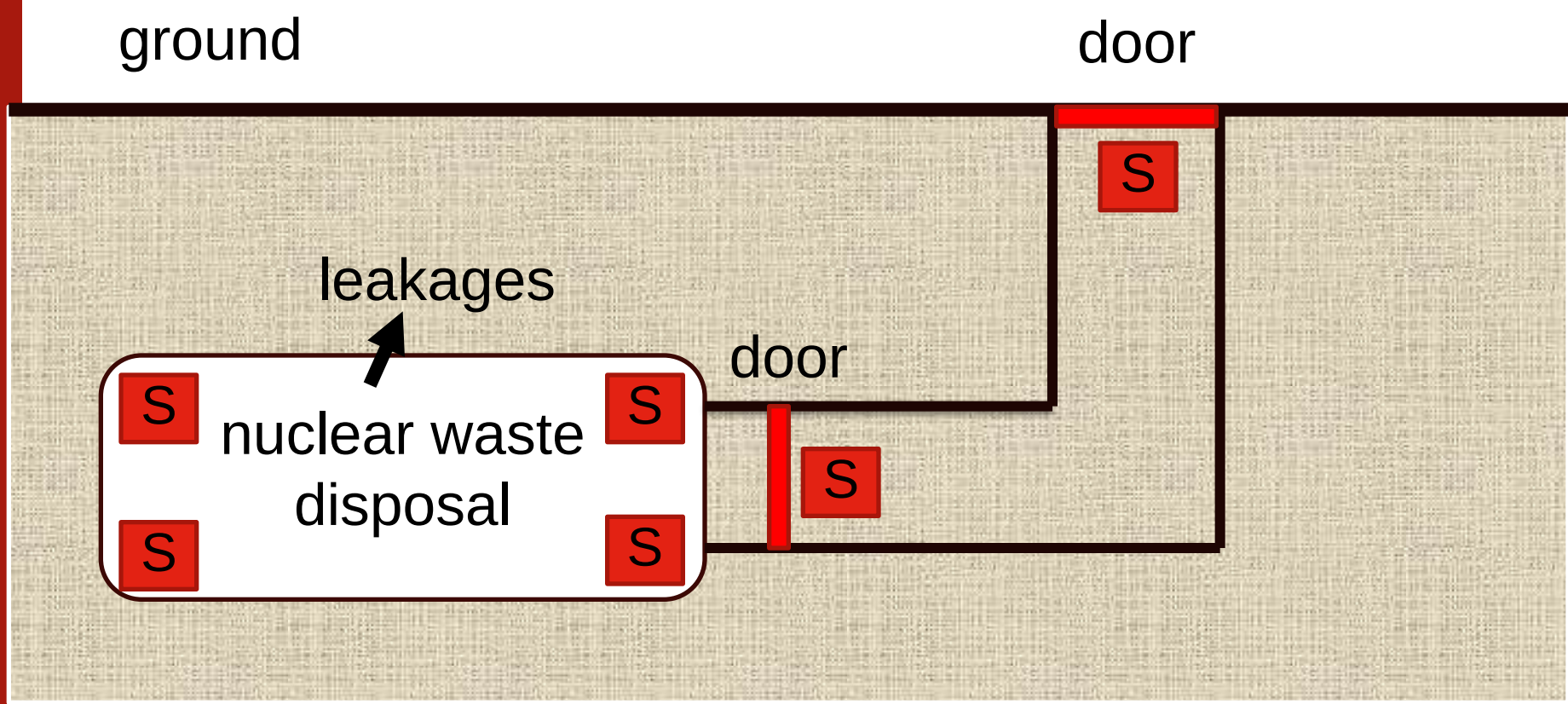
Monitoring of high doses of radiation acting on the reactor covers – safety „caps”.



working reactors / industry facility

Sensors of high doses of radiation – potential application

Monitoring of doses coming from nuclear waste disposal.



Sensors of high doses of radiation – potential application

High radiation coexist with another treats

- High temperature
- High electromagnetic / magnetic field
- Explosion risk
- Poisonous gases

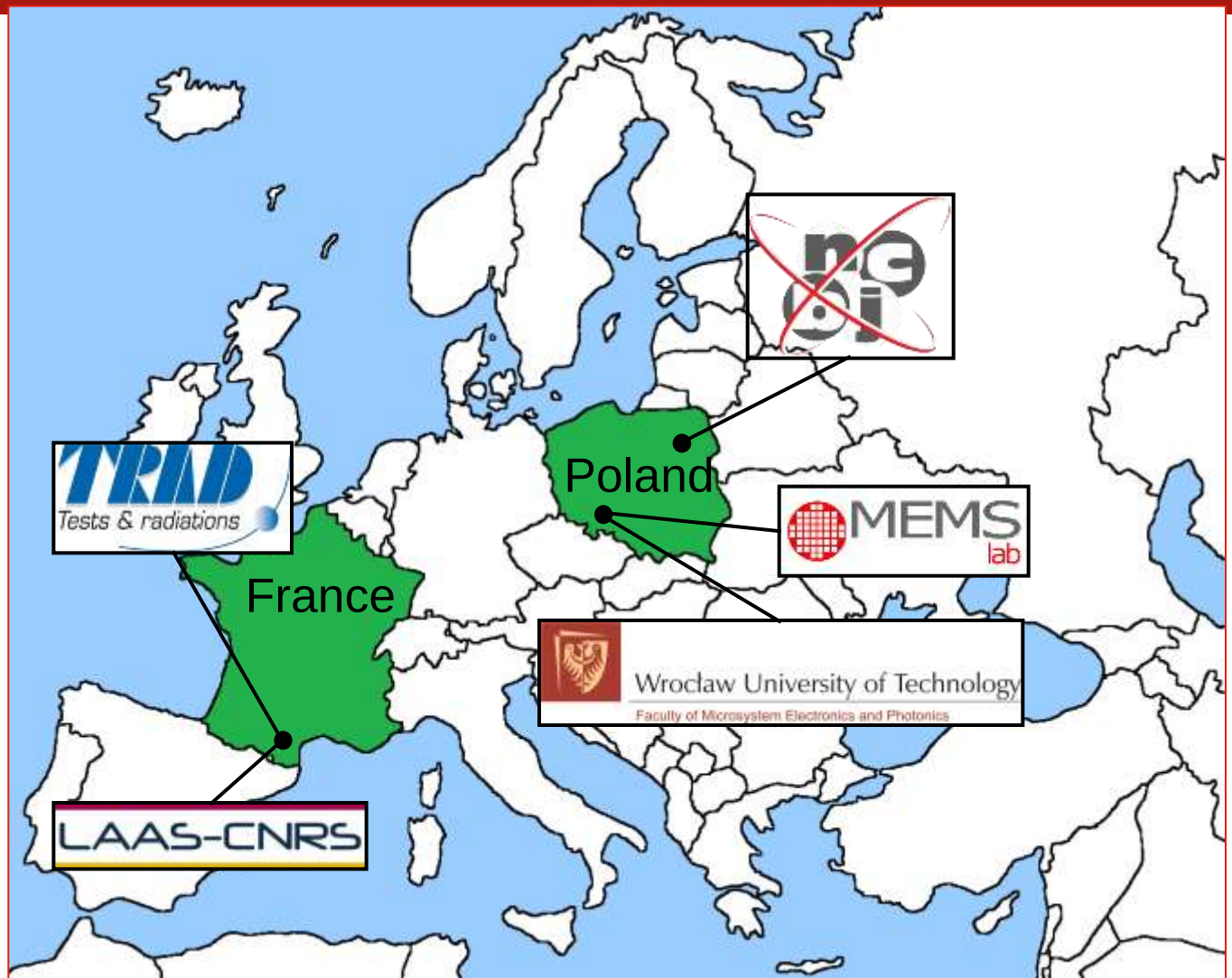
Sensor and sensing head are:

- **resistant against high temperature (up to 300 ºC)**
- **EX standard ready**
- **wireless**

More information in papers

- I. Augustyniak, P. Knapkiewicz, J. Dziuban, M. Olszacki, P. Pons, MEMS high-doses radiation sensor, The 17th International Conference on Solid-State Sensors, Actuators and Microsystems, **Transducres 2013**, Barcelona, 16-20 June 2013, p. 1503-1506, ISBN 978-1-4673-5981-8,
- M. Olszacki, M. Matusiak, I. Augustyniak, P. Knapkiewicz, J. Dziuban, P. Pons and E. Debourg, Measurement of the high gamma radiation dose using the MEMS based dosimeter and radiolisys effect,, **24th Micromechanics and Microsystems Europe Conference**, September 1-4, 2013 Hanasaari Finland, p. 33-36,

Acknowgelements



MEMSlab Team

MEMS lab

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MEMSlab team of Faculty of Microsystem Electronics and Photonics of Wroclaw University of Technology – picture taken in the 14th century Castle, Ryn, Poland